Clouds and the Earth's Radiant Energy System (CERES)

Data Management System

Software Design Document

Regrid Humidity and Temperature Fields
(Subsystem 12.0)

ARCHITECTURAL DRAFT

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Release 1.0
April 1996

Preface

The Clouds and the Earth's Radiant Energy System (CERES) Data Management System supports the data processing needs of the CERES science research to increase understanding of the Earth's climate and radiant environment. The CERES Data Management Team works with the CERES Science Team to develop the software necessary to support the science algorithms. This software, being developed to operate at the Langley Distributed Active Archive Center (DAAC), produces an extensive set of science data products.

The Data Management System consists of 12 subsystems; each subsystem represents a stand-alone executable program. Each subsystem executes when all of its required input data sets are available and produces one or more archival science products.

The documentation for each subsystem describes the software design at various stages of the development process and includes items such as Software Requirements Documents, Data Products Catalogs, Software Design Documents, Software Test Plans, and User's Guides.

This version of the Software Design Document records the architectural design of each Subsystem for Release 1 code development and testing of the CERES science algorithms. This is a PRELIMINARY document, intended for internal distribution only. Its primary purpose is to record what was done to accomplish Release 1 development and to be used as a reference for Release 2 development.

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12.0 Introduction

The Clouds and the Earth's Radiant Energy System (CERES) program is a key component of the Earth Observing System (EOS). The CERES instrument will provide radiometric measurements of the Earth's atmosphere from three broadband channels: a shortwave channel (0.2 - 5.0μm), a total channel (0.2 - 50μm), and an infrared window channel (8-12μm). The CERES instrument is an improved model of the Earth Radiation Budget Experiment (ERBE) scanner, which was flown aboard the Earth Radiation Budget Satellite (ERBS) from November 1984 until February 1990 in a 57-deg inclination orbit. During much of the same time period, additional ERBE scanner instruments flew on the National Oceanic and Atmospheric Administration (NOAA) Sun-synchronous, polar orbiting satellites NOAA-9 and NOAA-10. By following the strategy of flying instruments on Sun-synchronous, polar orbiting satellites with instruments on satellites with lower inclination orbits, ERBE successfully reduced temporal sampling errors. Following the same strategy, the first CERES instrument is expected to be launched in 1997 aboard the Tropical Rainfall Measuring Mission (TRMM), a satellite with an orbital inclination of 35 degrees. Additional CERES instruments will be flown aboard the polar orbiting EOS-AM and EOS-PM platforms. The first EOS-AM platform is expected to be launched in 1998, while the first EOS-PM platform is expected to be launched in 2000. As an improvement to the ERBE strategy, CERES will include cloud imager data and other atmospheric parameters in order to increase the certainty of the data and improve the consistency between the cloud parameters and the radiation fields.

The CERES Regrid Humidity and Temperature Fields Subsystem (12.0) ingests meteorological, ozone, and aerosol data from several different external sources and combines these data into one file, the Meteorological, Ozone, and Aerosol (MOA) file. The MOA is an hourly file, spatially organized according to a 1.25-deg equal-area grid, conforming to CERES requirements. Since the input data from the different external sources do not conform to a common spatial and temporal grid system, this Subsystem spatially and temporally interpolates the input data to conform with CERES standards. Software developed by the CERES Clouds, Surface and Atmospheric Radiation Budget (SARB), and Time Interpolation and Spatial Averaging (TISA) Working Groups all require access to the data contained in the MOA.

For Release 1, the CERES SARB and Clouds working groups have supplied the input data sets. For postlaunch processing; however, the EOS Data and Information System (EOSDIS) Core System (ECS) is responsible for obtaining the external ancillary input data required by this Subsystem. ECS will perform the initial ingestion of these data and store them in an easily accessible format. The spatial and temporal resolutions of these data will not be altered by ECS. Once ECS has performed the initial ingestion, the data will be made available to the various EOS projects, including CERES. ECS will provide a scheduler that will track the availability of these input data sets and subsequently control processing of Product Generation Executives (PGEs) such as the Regrid Humidity and Temperature Fields Subsystem. The CERES Science Team will decide on an allowable lag time between the measurement of CERES data and the execution of this Subsystem. This lag time should be built into the EOSDIS processing scheduler, and should allow for the accumulation of the necessary input data from the external sources. If all of the necessary data are not available from the external sources after this lag time, the Regrid Humidity and Temperature Fields Subsystem may access a climatology approved by the CERES Science Team.

This Subsystem first interpolates the input data horizontally, which is the domain where the data have the smallest variability. Next, the data are temporally interpolated. Lastly, the data are interpolated in the vertical domain, where the data have the largest variability. (Note: Not every parameter will need to be interpolated in all three domains.) Data interpolated in the vertical domain provide vertical profiles at pressure levels selected by the CERES Science Team. Currently, the levels in these profiles number 58--three floating levels at the surface and 55 fixed levels beginning at 1000 hPa and continuing up to 0.1 hPa.

The external products that Subsystem 12.0 will access in Release 1 include aerosol optical depth data sets supplied by Drs. Rachel Pinker and Larry Stowe; column ozone data from the International Satellite Cloud Climatology Project (ISCCP); and meteorological data, such as temperature, humidity, and wind speed profile data, obtained from a preliminary version of the National Centers for Environmental Prediction (NCEP) T62L28 reanalysis data set.

The MOA file, the primary output product from the Regrid Humidity and Temperature Fields Subsystem, will include the same meteorological data as the input products, except on a common temporal and spatial grid system as previously specified.

The Architectural Design for this Subsystem is discussed below. The input products required for Subsystem processing, along with the output products generated, are discussed in Appendix A.

Architectural Design

A single run of the Regrid Humidity and Temperature Fields Subsystem ingests input data spanning one 24-hour time period and produces 24 1-hour MOA output files. Processing begins by invoking Subroutine Start12 to obtain data to be used throughout Subsystem processing. Such parameters include the data date, parameters used in the various regridding processes, and seasonal climatological data used for data missing from the input data sets. Parameters used in the regridding processes are defined either via calls to the CERElib reference_grid module or through reading input files.

After Subsystem processing initialization is completed, Subroutine Aer_Drv drives the generation of the aerosol optical depth data. Two different data sets are used to generate the MOA aerosol data. The first set of data is a monthly average of October 1986 data supplied by Dr. Rachel Pinker on the ISCCP 2.5-deg equal-area grid. These data are ingested and horizontally interpolated to the CERES 1.25-deg equal-area ISCCP-type grid. Next, an average of October 1989 and October 1990 data supplied by Dr. Larry Stowe of NOAA is ingested and horizontally interpolated from a 1-deg equal-angle grid to the CERES grid. Pinker’s and Stowe’s data are then merged, with Stowe’s data taking precedence for CERES regions for which both input data sets contain non-default data.

The processes to define both the column ozone values and the ozone vertical profile values are driven by Subroutine ColO3_Drv. The ISCCP C-1 column ozone data set is ingested and horizontally interpolated from the ISCCP 2.5-deg equal-area grid to the CERES grid. Then, for each CERES region, level dependent weighting factors are applied to the column ozone value to produce a vertical profile of ozone mixing ratios for the 55 fixed MOA vertical pressure levels. The profile values for the three floating surface levels will be interpolated once the surface pressure has been ingested and processed later in Subsystem processing.

Subroutine Met_Drv drives the processing of the meteorological data. NCEP T62L28 input data files contain the surface orography, surface pressure, vertical profiles of virtual temperature, specific humidity and wind speed data, and the sigma levels corresponding to the vertical profiles. These data are available every six hours (hours are 00, 06, 12, and 18 daily). The data for hour 00 are ingested, converted from wave data to gridded data (192 regions longitudinally by 94 regions latitudinally, for a total of 18048 regions), and then horizontally interpolated to conform with the CERES grid. Data for hour 06 are then ingested and go through the same processes as the data for hour 00. Then, for each hour between hours 00 and 06, the data for each region are interpolated temporally and vertically. Since the NCEP data only extend from the surface to 5 hPa, and the values of the specific humidity above 300 hPa are unreliable, climatological data is substituted for portions of the profiles. Temperature data above 5 hPa are based on a climatology provided by the CERES Science Team, and specific humidity values above 300 hPa are based on a climatology produced by the Stratospheric Aerosol and Gases Experiment (SAGE). A vertical profile of geopotential height for each region is calculated once the vertical temperature profile for that region is complete. At this point, the pressures at the floating surface levels are known, and the corresponding values in the ozone profile can be interpolated. The skin temperature data written to the MOA output files are obtained from a second set of NCEP files. Due to the requirement for only one parameter from these files and the large size of these files, an off-line process has isolated the skin temperature data and stored them on daily files that are accessed during Subsystem processing. Once all of the data for a single region are available, they are written to the appropriate MOA output file.

One known change for Release 2 for Subsystem 12.0 is the inclusion of a Quality Control (QC) report to display run-time statistics. Another probable change is the inclusion of logic to process microwave humidity data. More elaborate logic to finalize Subsystem processing than is included with Release 1 will also probably need to be developed for Release 2. This logic will be driven by Subroutines MWH_Drv and Finish12, which are shown in the Subsystem design.

Figure 12-1 is a flow diagram of Subsystem 12.0 processing. Figure 12-2 is the structure chart of the routines used during Subsystem processing. Table 12-1 gives a brief description of each subroutine and indicates in which FORTRAN module it is located.

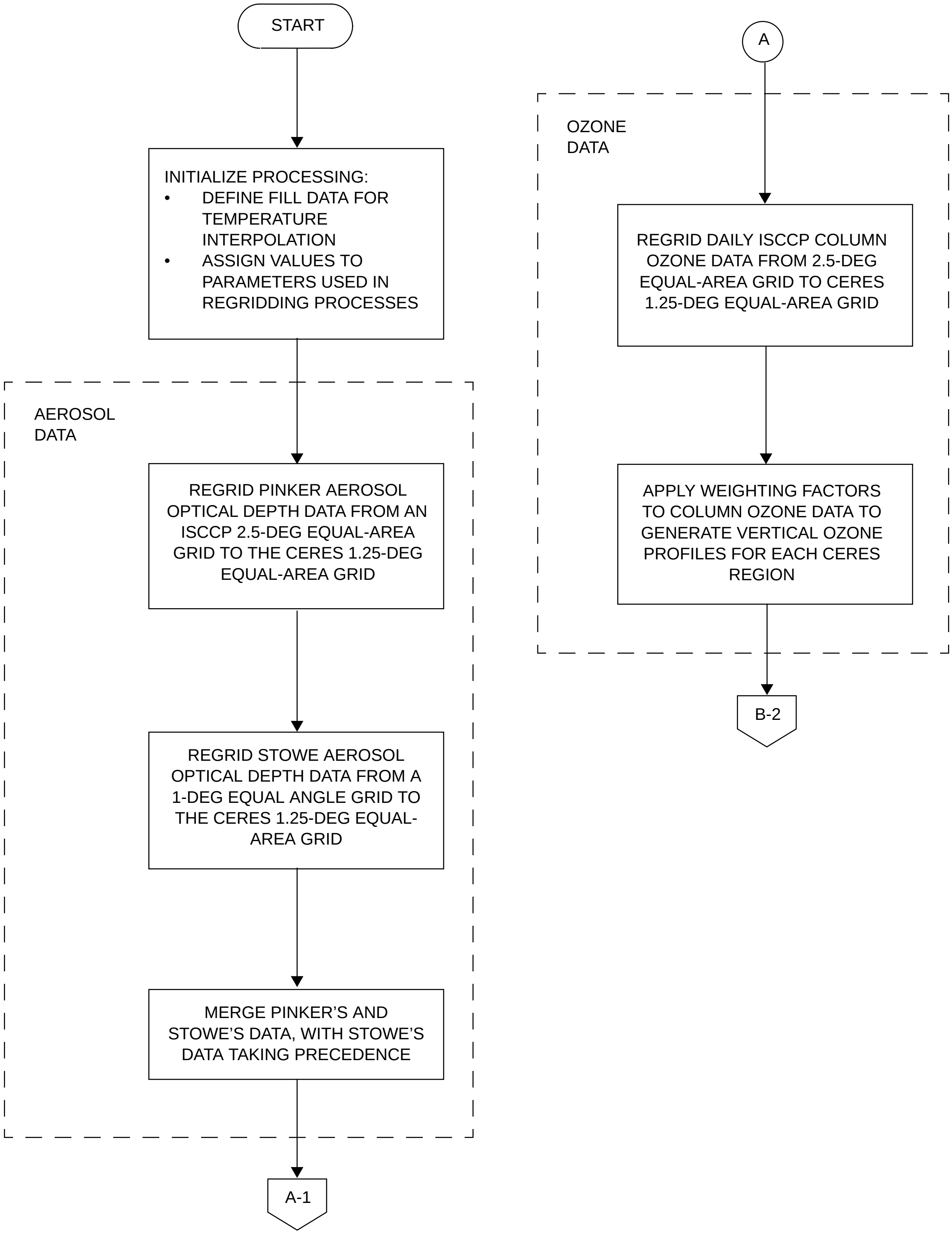


Figure 12-1. Flow Diagram of the Regrid Humidity and Temperature Fields Subsystem (1 of 2)

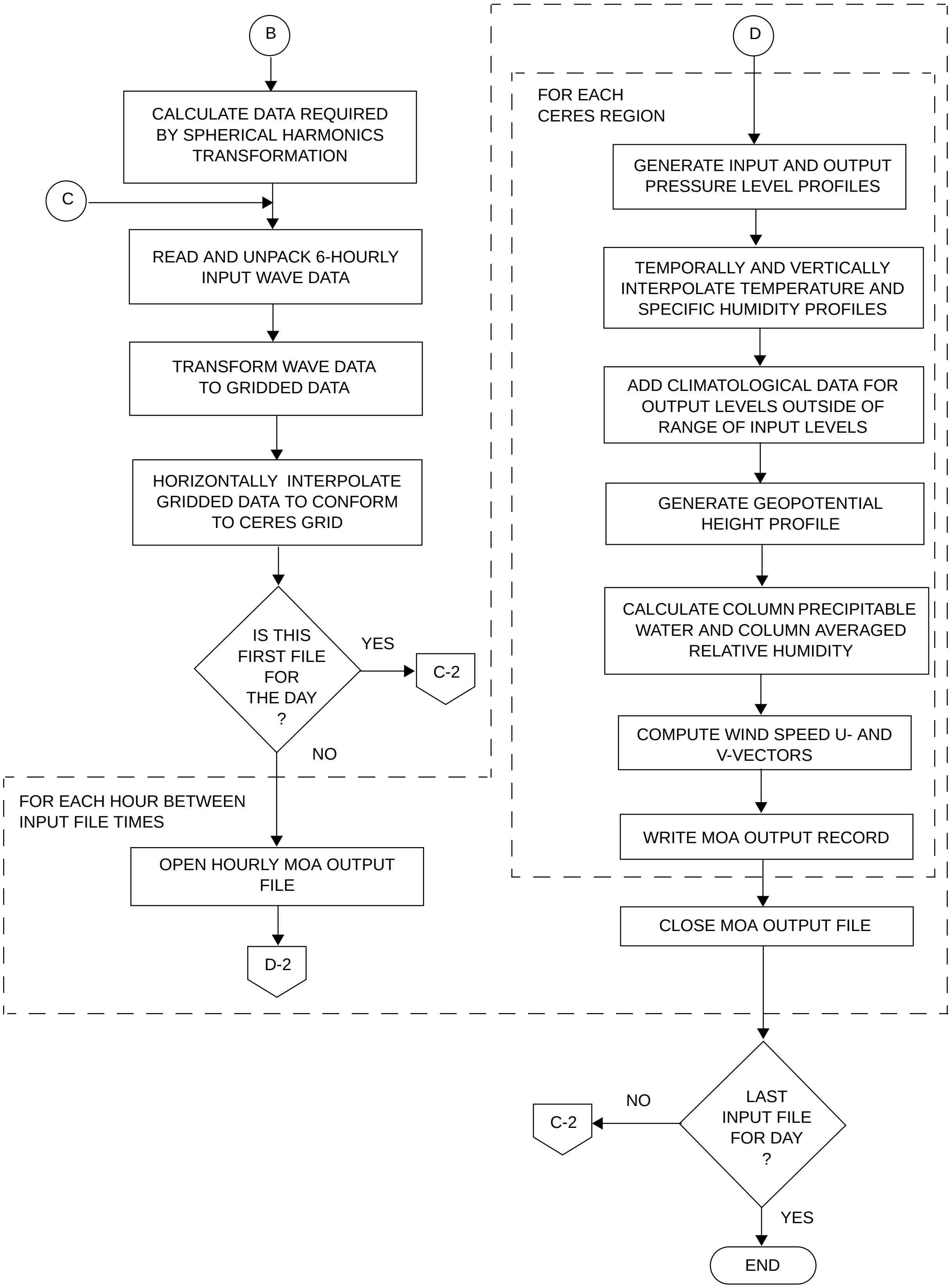


Figure 12-1. Flow Diagram of the Regrid Humidity and Temperature Fields Subsystem (2 of 2)

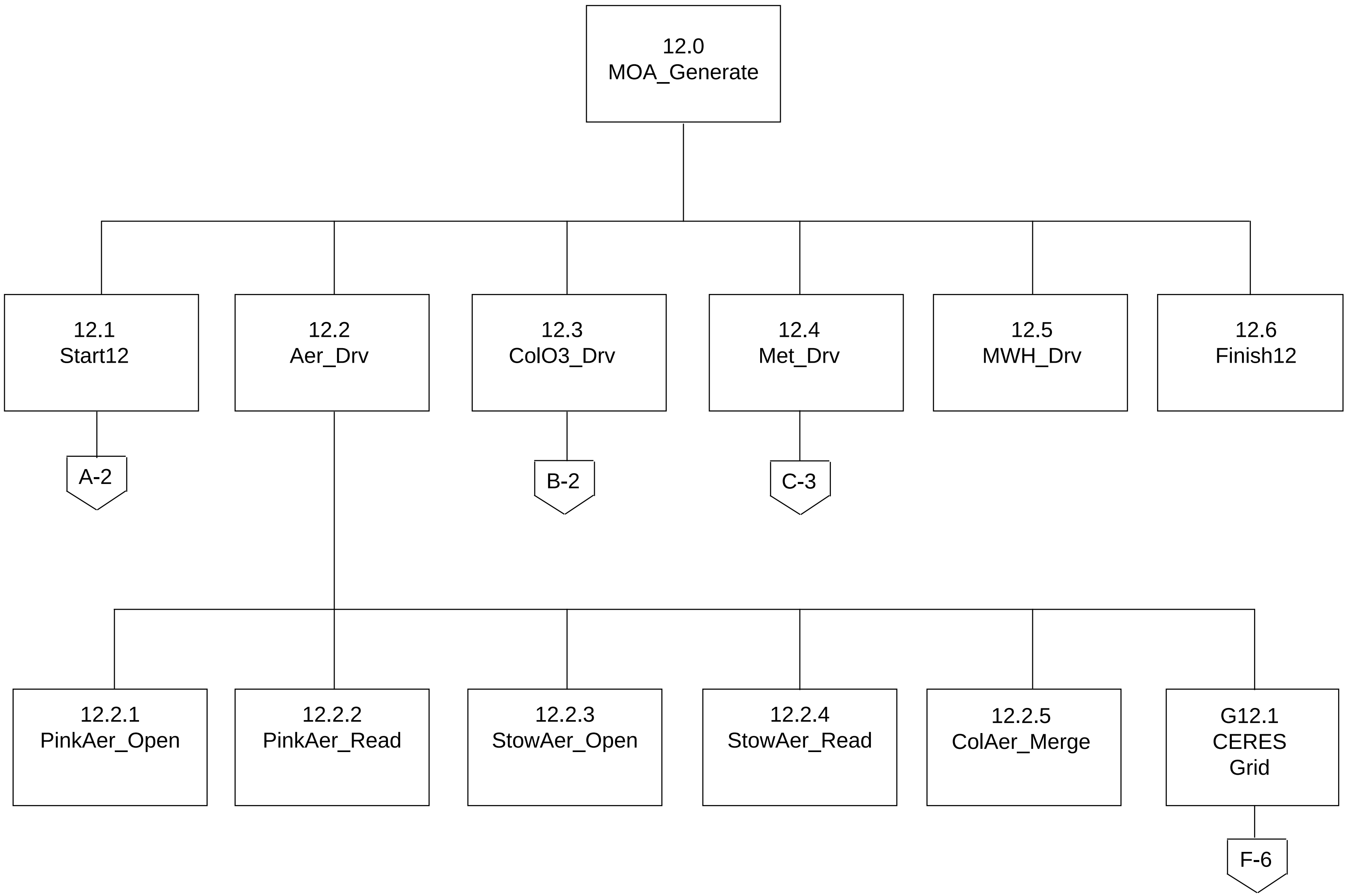


Figure 12-2. Structure Chart of the Routines Used During Subsystem Processing (1 of 6)

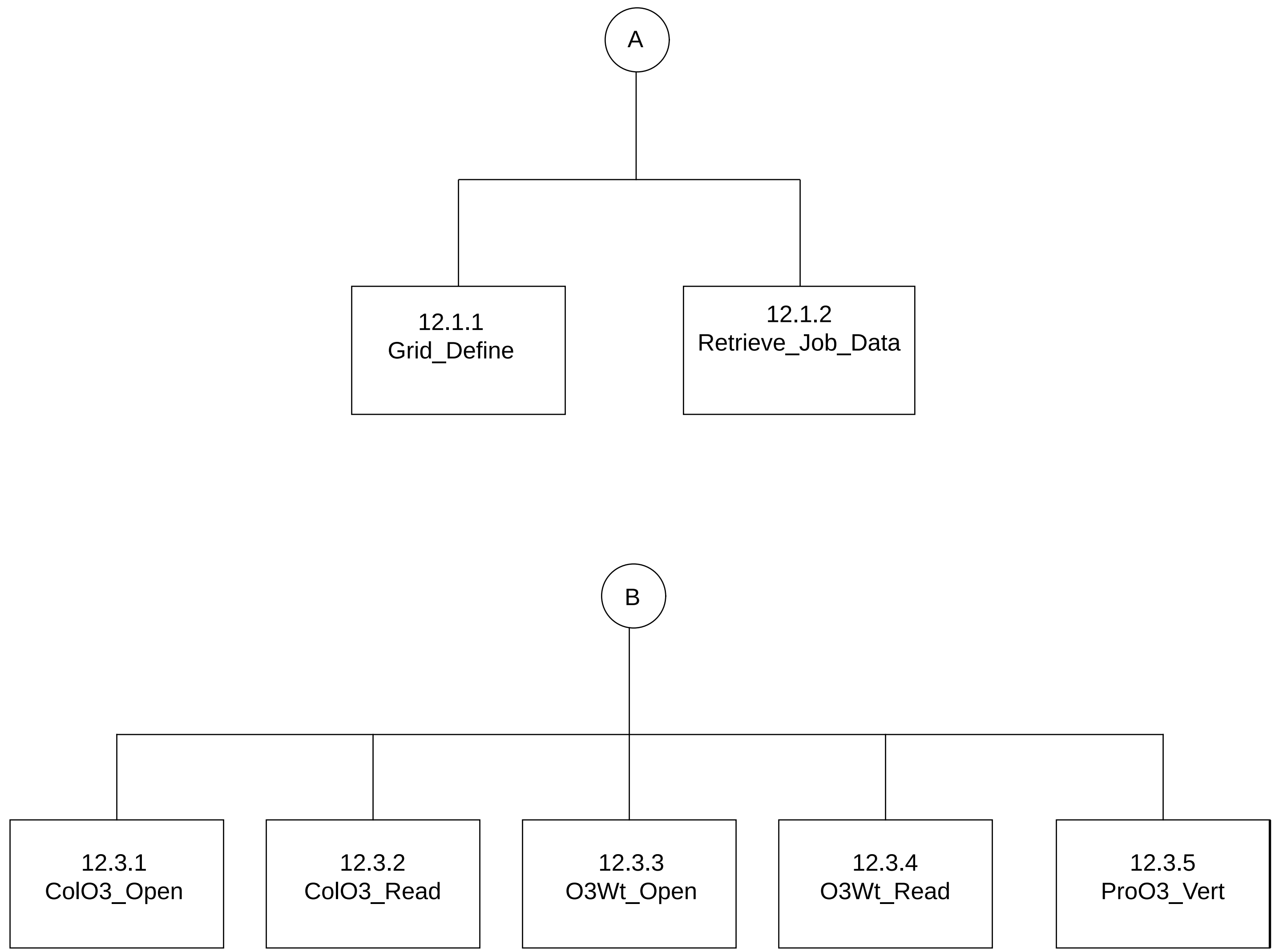
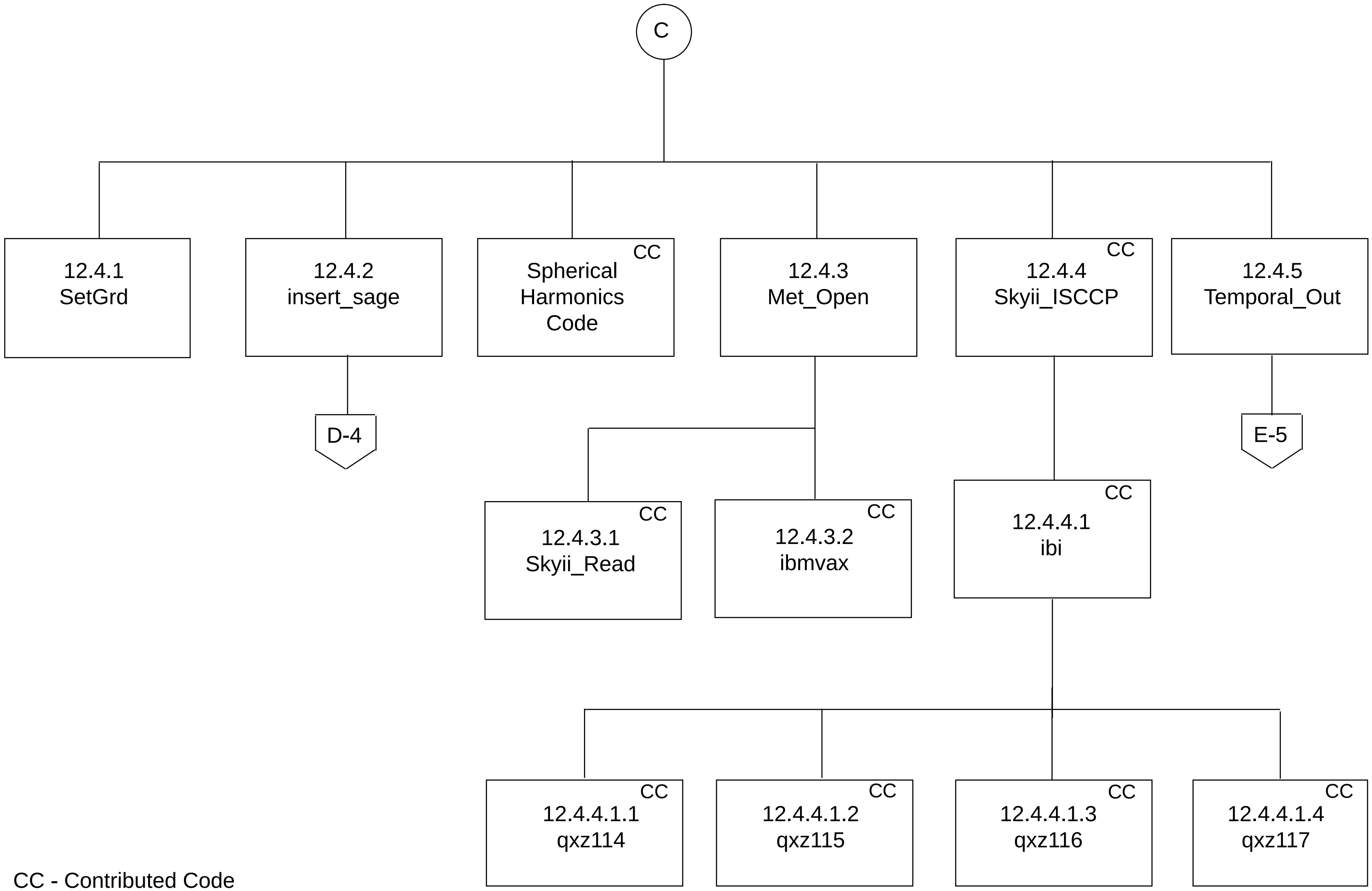


Figure 12-2. Structure Chart of the Routines Used During Subsystem Processing (2 of 6)



CC - Contributed Code

Figure 12-2. Structure Chart of the Routines Used During Subsystem Processing (3 of 6)

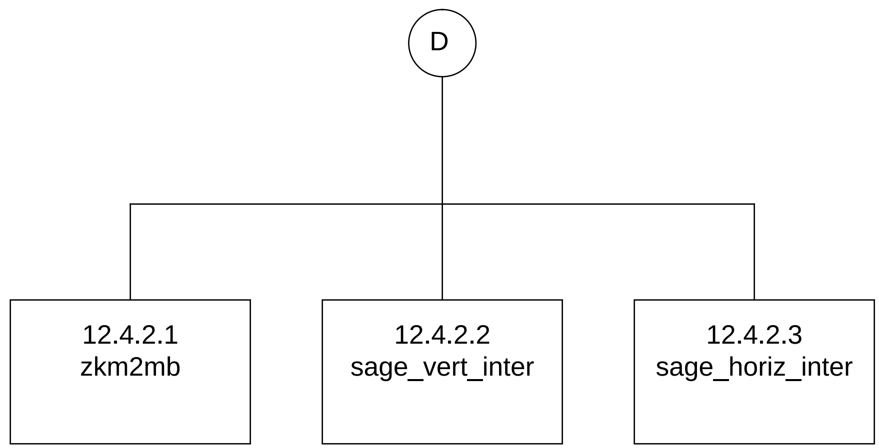
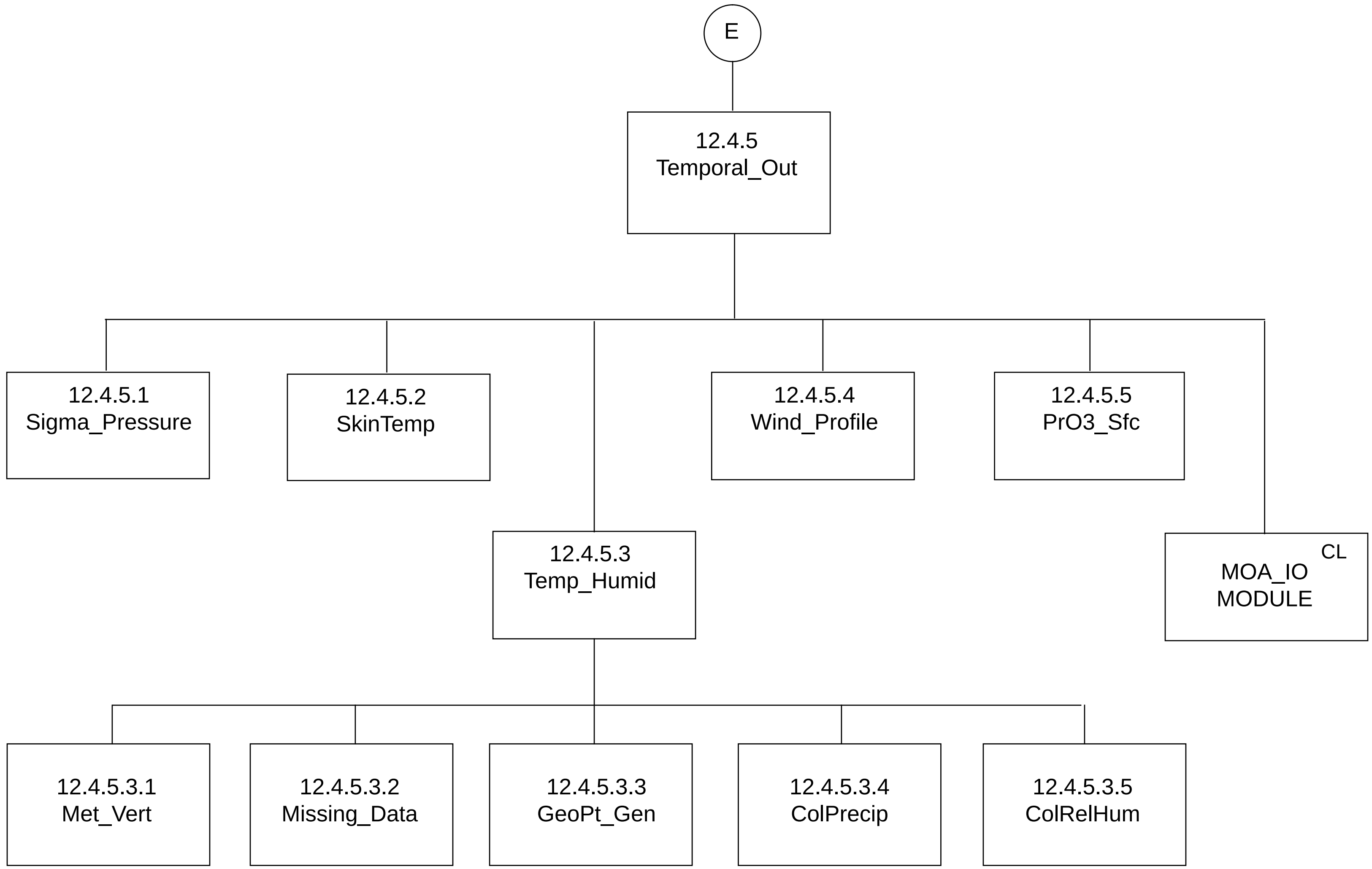


Figure 12-2. Structure Chart of the Routines Used During Subsystem Processing (4 of 6)



CL - CERESlib

Figure 12-2. Structure Chart of the Routines Used During Subsystem Processing (5 of 6)

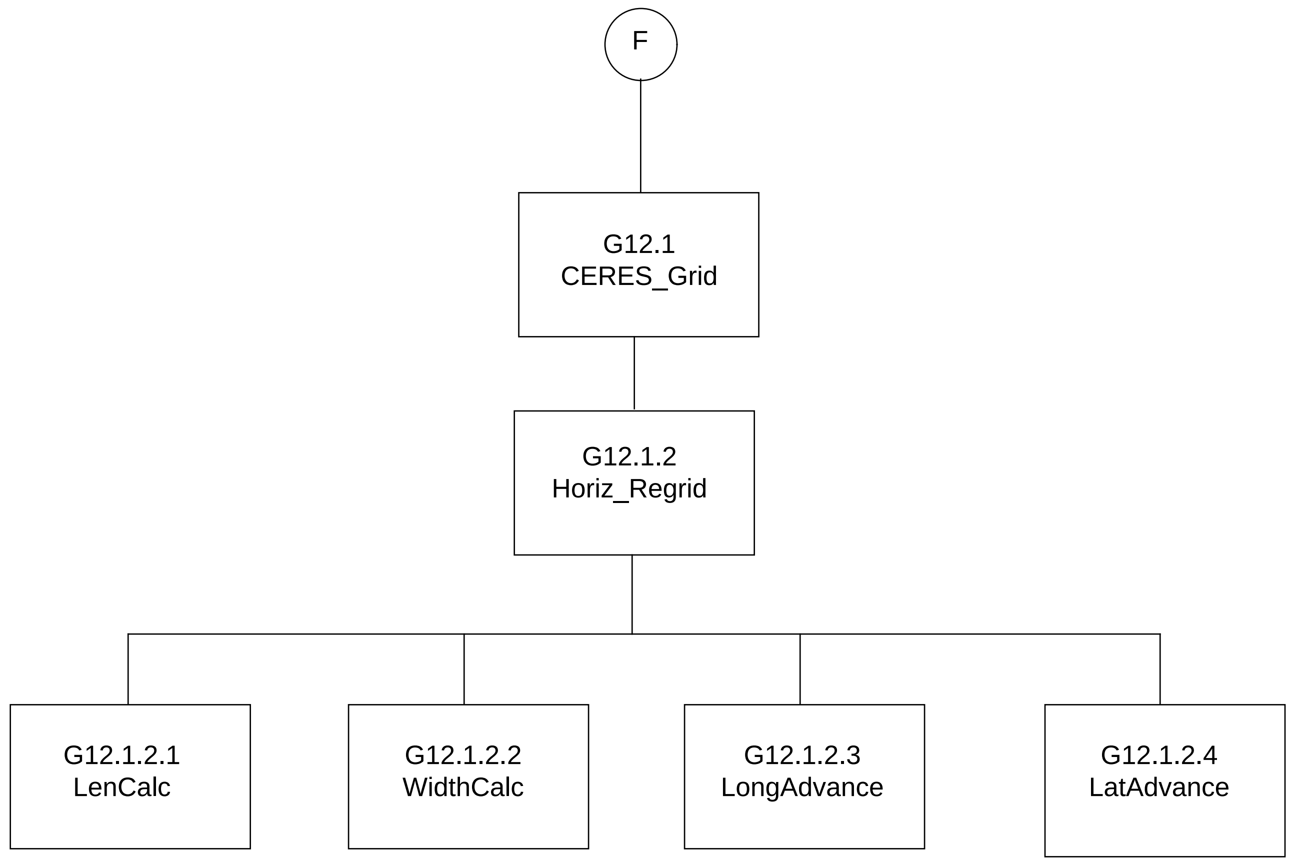


Figure 12-2. Structure Chart of the Routines Used During Subsystem Processing (6 of 6)

Table 12-1. Brief Description of Each Subroutine (1 of 3)

SUBROUTINE NAME	SUBROUTINE NUMBER	MODULE NAME	DESCRIPTION
MOA_Generate	12.0	n/a	Drives subsystem processing
Start12	12.1	Init_SS12	Initializes subsystem processing
Grid_Define	12.1.1	Init_SS12	Reads NAMELISTs of parameter values associated with different grids
Retrieve_Job_Data	12.1.2	Init_SS12	Captures run-time parameters, such as data date
Aer_Drv	12.2	AEROSOLS_MOD	Drives processing of aerosol data
PinkAer_Open	12.2.1	AEROSOLS_MOD	Opens file of Pinker's aerosol optical depth data
PinkAer_Read	12.2.2	AEROSOLS_MOD	Reads file of Pinker's aerosol optical depth data
StowAer_Open	12.2.3	AEROSOLS_MOD	Opens file of Stowe's aerosol optical depth data
StowAer_Read	12.2.4	AEROSOLS_MOD	Reads file of Stowe's aerosol optical depth data
ColAer_Merge	12.2.5	AEROSOLS_MOD	Merges Pinker's and Stowe's data sets
ColO3_Drv	12.3	COL_OZONE	Drives processing of ozone data
ColO3_Open	12.3.1	COL_OZONE	Opens column ozone file
ColO3_Read	12.3.2	COL_OZONE	Reads column ozone data for current day
O3Wt_Open	12.3.3	COL_OZONE	Opens file of ozone vertical profile weighting factors
O3Wt_Read	12.3.4	COL_OZONE	Reads file of ozone vertical profile weighting factors
ProO3_Vert	12.3.5	COL_OZONE	Applies ozone vertical profile weighting factors to column ozone values to generate the vertical ozone profile
Met_Drv	12.4	Met_Main	Drives processing of the meteorological data
SetGrd	12.4.1	Met_Main	Calculates data required by the spherical harmonics process
insert_sage	12.4.2	SAGE_Replace	Retrieves SAGE climatological humidity data
zkm2mb	12.4.2.1	SAGE_Replace	Converts geopotential height to pressure

Table 12-1. Brief Description of Each Subroutine (2 of 3)

SUBROUTINE NAME	SUBROUTINE NUMBER	MODULE NAME	DESCRIPTION
sage_vert_inter	12.4.2.2	SAGE_Replace	Vertically interpolates SAGE data to CERES levels
sage_horiz_inter	12.4.2.3	SAGE_Replace	Horizontally interpolates SAGE data to CERES grid
Met_Open	12.4.3	Met_Ingest	Opens 6-hourly NCEP sigma file
Skyii_Read	12.4.3.1	Met_Ingest	Reads data from 6-hourly NCEP sigma file
ibmvax	12.4.3.2	Met_Ingest	Unpacks data from 6-hourly NCEP sigma file
Skyii_ISCCP	12.4.4	Met_Horiz	Drives horizontal interpolation of NCEP data to conform to CERES grid
ibi	12.4.4.1	Met_Horiz	Subroutine of Sbr. Skyii_ISCCP
qxz114	12.4.4.1.1	Met_Horiz	Function of Sbr. ibi
qxz115	12.4.4.1.2	Met_Horiz	Subroutine of Sbr. ibi
qxz116	12.4.4.1.3	Met_Horiz	Subroutine of Sbr. ibi
qxz117	12.4.4.1.4	Met_Horiz	Subroutine of Sbr. ibi
Temporal_Out	12.4.5	Met_Main	Drives processing of meteorological data from the point of temporal interpolation to point of writing data to the output product
Sigma_Pressure	12.4.5.1	Met_Main	Converts the NCEP sigma levels to pressure levels
SkinTemp	12.4.5.2	Met_Main	Reads hourly skin temperature data from input file
Temp_Humid	12.4.5.3	Temperature_Humidity	Drives the calculation of the vertical profiles for temperature, specific humidity, and geopotential height for a given CERES region
Met_Vert	12.4.5.3.1	Temperature_Humidity	Drives the vertically interpolation of meteorological data
Missing_Data	12.4.5.3.2	Temperature_Humidity	Fills in the portions of the vertical temperature and humidity profiles that are not available from the NCEP sigma data
GeoPt_Gen	12.4.5.3.3	Temperature_Humidity	Generates the geopotential height profile
ColPrecip	12.4.5.3.4	Temperature_Humidity	Computes the total column precipitable water value
ColRelHum	12.4.5.3.5	Temperature_Humidity	Computes the column-averaged relative humidity value

Table 12-1. Brief Description of Each Subroutine (3 of 3)

SUBROUTINE NAME	SUBROUTINE NUMBER	MODULE NAME	DESCRIPTION
Wind_Profile	12.4.5.4	Met_Main	Derives the u- and v-vector wind speed values
ProO3_Sfc	12.4.5.5	Met_Main	Interpolates vertical ozone profile values for the floating surface levels
MWH_Drv	12.5	n/a	Drives processing of microwave humidity (not developed for Release 1)
Finish12	12.6	n/a	Drives Subsystem finalization procedures (not developed for Release 1)
CERES_Grid	G12.1	Horiz_Inter	Provides interfaces for Sbr. Horiz_Regrid
Grid_Angle	G12.1.1	Horiz_Inter	Maps scalar variables associated with equal-angle grids to arrays for use in Sbr. Horiz_Regrid
Horiz_Regrid	G12.1.2	Horiz_Inter	Converts data from a equal-area or equal-angle grid to data on a CERES grid
LenCalc	G12.1.2.1	Horiz_Inter	Calculates length of CERES region contained within a given input data region
WidthCalc	G12.1.2.2	Horiz_Inter	Calculates width of CERES region contained within a given input data region
LongAdvance	G12.1.2.3	Horiz_Inter	Advances to next CERES and/or input data grid region in current latitudinal zone
LatAdvance	G12.1.2.4	Horiz_Inter	Advances to next CERES and/or input data latitudinal grid zone

Acronyms and Abbreviations

CERES	Clouds and the Earth's Radiant Energy System
DAAC	Distributed Active Archive Center
ECS	EOSDIS Core System
EOS	Earth Observing System
EOS-AM	EOS Morning Crossing Mission
EOSDIS	EOS Data and Information System
EOS-PM	EOS Afternoon Crossing Mission
ERBE	Earth Radiation Budget Experiment
ERBS	Earth Radiation Budget Satellite
hPa	Hecto Pascals
ISCCP	International Satellite Cloud Climatology Project
MOA	Meteorological, Ozone, and Aerosol
NCEP	National Centers for Environmental Prediction
NOAA	National Oceanic and Atmospheric Administration
PAER	Pinker Aerosol Optical Depth Data
PGE	Product Generation Executives
QC	Quality Control
SAER	Stowe Aerosol Optical Depth Data
SAGE	Stratospheric Aerosol and Gases Experiment
SARB	Surface and Atmospheric Radiation Budget
SWV	SAGE Water Vapor
TISA	Time Interpolation and Spatial Averaging
TRMM	Tropical Rainfall Measuring Mission

APPENDIX A

Input and Output Products for the CERES Regrid Humidity and Temperature Fields Subsystem

Appendix A - Input and Output Products for the CERES Regrid Humidity and Temperature Fields Subsystem

A.1 Input Products

A.1.1 Aerosol Optical Depth Products

CERES uses two different aerosol optical depth data sets. One set, supplied by Dr. Rachel Pinker, is used for the data over non-ocean surfaces. The other set, supplied by Dr. Larry Stowe (NOAA), contains aerosol optical depth data over ocean regions. Subsystem 12.0 merges the data from these two sets. In the event that both data sets contain data for a CERES region, the Stowe data is used.

A.1.1.1 Pinker Aerosol Optical Depth Data (PAER)

The Pinker aerosol data set is spatially organized according to the 2.5-deg equal-area ISCCP grid. These data are regridded to the CERES 1.25-deg equal-area grid during Subsystem processing. Data are available at 3-hour intervals. In an off-line process executed prior to Subsystem processing, a month's worth of data are averaged and stored as input into Subsystem 12.0.

A.1.1.2 Stowe Aerosol Optical Depth Data (SAER)

The Stowe aerosol data set is spatially organized according to a 1-deg by 1-deg equal-angle grid. These data are regridded to the CERES 1.25-deg equal-area grid during Subsystem processing. Data coverage is from -70S to 70N and from 180W Eastward to 179E. October 1986 is the data set selected for CERES Release 1 testing. Since there is no Stowe data set for that year, the values for the October 1989 and October 1990 data sets were averaged in an off-line process prior to Subsystem processing.

A.1.2 Meteorological Data

A.1.2.1 NCEP Reanalysis Data

The NCEP has supplied a preliminary version of their T62L28 reanalysis data set. This data set contains 62 waves of data for 28 atmospheric levels of temperature, specific humidity, and wind speed data. These data are transformed from wave data to a Guassian grid, and then converted to the CERES 1.25-deg equal-area grid during Subsystem processing.

A.1.2.2 SAGE Water Vapor (SWV) Climatology

The SAGE Water Vapor climatology is temporally organized according to season.

A.1.2.3 NCEP Skin Temperature

The NCEP skin temperature files are generated by an off-line process that isolates the skin temperature data for each Gaussian region from the NCEP flux files, available on a six-hourly basis. The off-line process also horizontally interpolates these data to the CERES grid and then temporally interpolates them to produce hourly values. Once the values for all regions are determined for an hour, they are written to the output file. A single output file will contain all of the skin temperature data for a 24-hour period.

A.1.3 Ozone Products

There are two ozone products that are to be supplied on the MOA output product: a column ozone value, and a profile of ozone mixing ratios. The profile of ozone mixing ratios is derived by applying level-dependent weighting factors to the column ozone values.

A.1.3.1 ISCCP C-1 Column Ozone Data

The ISCCP C-1 column ozone data is spatially organized on the 2.5-deg equal-area ISCCP grid. These data are regridded to the CERES 1.25-deg equal-area grid during Subsystem processing. While the column ozone is stored on the ISCCP C-1 data set eight times a day, the values are the same throughout the day. Prior to Subsystem processing, the daily column ozone values were isolated from the remainder of the ISCCP C-1 product in an off-line process.

A.1.3.2 Ozone Vertical Profile Weighting Factors

The ozone vertical profile weighting factors are based on a climatology of vertical ozone profiles generated by Eric Flemming of Goddard Space Flight Center. Since only data for October 1986 will be processed through CERES Release 1 software, weighting factors for October 1986 have been produced. While the climatology provided by Eric Flemming concentrated on atmospheric levels in the stratosphere, the weighting factors used by CERES are tailored to the 55 fixed pressure levels corresponding to MOA data. There are 18 weighting factors for each MOA level--one factor for each 10-deg latitudinal zone.

A.1.4 Regional Centers (RegCenters)

RegCenters is a binary file containing the latitudinal and longitudinal coordinates for the centers of each region included on both the CERES and NCEP Gaussian grids. CERES region coordinates were determined through a call to the CERESlib routine GetCenter_Ceres (Module reference_grid), while the Gaussian centers were determined through a contributed subroutine, ISCCPibis.

A.1.5 NGrid12

NGrid12 is a NAMELIST file containing data required in the various regridding processes executed by Subsystem 12.0. These data include, for each grid system (CERES, ISSCP 2.5-deg equal-area, Stowe's 1-degree equal angle), the number of latitudinal zones for each grid, the number of regions in each zone, the beginning and ending regions for each zone, and the region size (height).

A.2 Output Products

A.2.1 MOA

The MOA is an hourly file, containing all of the MOA data for each CERES region. These data include vertical profiles of temperature, specific humidity, geopotential height, and ozone, all as a function of pressure (hPa). The pressure levels include the surface, surface-10, surface-20, and the following fixed levels:

Table A-1. MOA Fixed Vertical Pressure Levels (hPa)

1000 - 750	725 - 450	430 - 135	125 - 15	10 - 0.1
1000.0	725.0	430.0	125.0	10.0
975.0	700.0	400.0	115.0	7.0
950.0	670.0	350.0	100.0	5.0
920.0	650.0	300.0	85.0	4.0
900.0	620.0	275.0	70.0	3.0
875.0	600.0	250.0	60.0	2.0
850.0	570.0	225.0	50.0	1.5
825.0	550.0	200.0	30.0	1.0
800.0	500.0	175.0	25.0	0.5
780.0	475.0	150.0	20.0	0.2
750.0	450.0	135.0	15.0	0.1

For regions where the surface pressure is lower than any of the fixed levels (e.g., a surface pressure of 945, which is lower than the levels for 1000, 975, and 950), the values for the fixed levels will be the CERES default value for 4-byte REALs. Each MOA also contains u- and v-vectors for wind speed at the atmospheric levels corresponding to the NCEP sigma levels (in Release 2, the wind speed data will be stored on the MOA for the subset of levels in Table A-1 that correspond with the needs of the Clouds Working Group). Nonprofile data on the MOA include the surface orography, the surface skin temperature, precipitable water, column averaged relative humidity, column ozone, and aerosol optical depth.

A.2.2 QC12

For each run of Subsystem 12.0 there will be one QC Report generated. It will contain, for each hour, the minimum and maximum values and the corresponding CERES region numbers for each parameter (excluding flags indicating input data source) on the MOA.